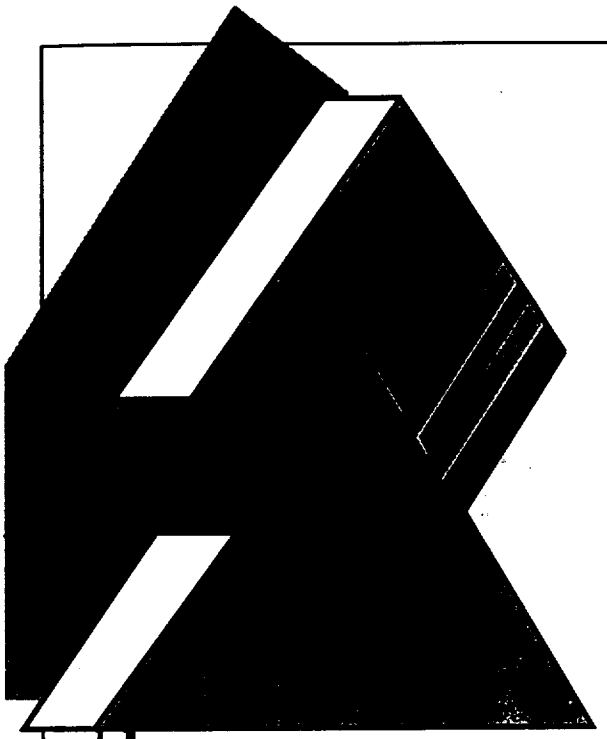

International Conference

February 17–19, 1993
Palais des Congres
Brussels, Belgium

Building Design, Technology & Occupant Well-being in Temperate Climates

Conference Information

Sponsoring Organizations

ATIC	Association Royale Belge Technique de l'Industrie du Chauffage, de la Ventilation et des Branches Connexes
ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers Inc.
IIR	International Institute of Refrigeration
REHVA	Federation of European Heating and Air-conditioning Associations
ABAV	Association Belge des Acousticiens
ABOK	Association of Engineers for Heating, Ventilation, Air-conditioning, Heat Supply, and Building Thermal Physics (CIS)
AEME	Agence Française de l'Environnement et de la Maîtrise de l'Energie
AIVC	Air Infiltration and Ventilation Centre (UK)
APPA	Association pour la Prévention de la Pollution Atmosphérique (France)
BOMA CANADA	Building Owners and Managers Association of Canada
CSTC-WTCB	Centre Scientifique et Technique de la Construction (Belgium)
IBI	Intelligent Buildings Institute of North America
IUAPPA	International Union of Air Pollution Prevention Associations
SOFRAB	Société Française de Microbiologie
SRBII	Société Royale Belge des Ingénieurs et Industriels

Building Design, Technology & Occupant Well-being in Temperate Climates International Conference

February 17-19, 1993, Palais des Congres Brussels, Belgium

Wednesday, February 17

Plenary Session: 8:30-10:15

Welcoming Address: Integrating Disciplines

E. M. Sterling, Conference Chairman, Theodor D. Sterling and Associates Ltd., Vancouver, BC, Canada

The last decade of the 20th century has seen increasing concerns about both man's impact on the environment and the environmental impact on man. Human activity occurs for the most part in and around buildings. These structures and the environments within them are the creation of man. Although buildings are not isolated from the global environment—and certainly they impact overall conditions through energy use and materials—by far their most important impact on human well-being is by way of the air quality and other conditions of the indoor space. These conditions are provided by a variety of disciplines concerned with building design, construction, and operation. Their impact on human well-being, on the other hand, is defined by a host of other disciplines concerned with health and well-being.

Our conference provides a forum for the exchange of new ideas, technology, and the results of scientific studies both within and across the many disciplines involved in creating quality buildings that promote human well-being. The cross-fertilization of ideas made possible by this conference is intended as a framework to improve the quality of buildings and building systems as well as methods of assessing their impact on human health and well-being.

Total System Environments to Satisfy Occupant Needs

R. A. Charles, President of ASHRAE, Charles & Braun Consulting Engineers, San Francisco, CA, U.S.A.

The design of building environments must be approached from a systems perspective. Consideration must be given to the inter-relationship among energy efficiency, occupant comfort, and indoor air quality, each an area covered by an ASHRAE Standard. This presentation will review the design criteria contained in these efforts to have an international standard developed on total building environments. Building design alone cannot fully satisfy occupant needs, however. This presentation will also discuss the need for building commissioning. Commissioning, performed in accordance with an ASHRAE guideline, will result in improved system performance and can result in the correction of problems which otherwise would go undetected for years, leading to premature equipment failures.

Governmental Legislation and Research Activities in REHVA Countries

B. Jacobsen, President of REHVA, Federation of European Heating and Air Conditioning Associations, Copenhagen, Denmark

Through its 19 member associations in Europe, REHVA has broad contact with a wide range of energy and environmental issues, particularly with respect to heating, ventilation, and air conditioning (HVAC). Historically, HVAC has developed in three steps:

- Step 1 was essential to develop simple technical solutions to heat and ventilate buildings and supply heating/cooling effects.
- Step 2 was the coordination of architecture and installations, demanding more space and big investments to meet the increasing demands for comfort.
- Step 3 was created by the energy crisis in the '70s. Raw material prices and costs to dispose of waste products suddenly had a high priority, and resources was the factor leading to new ideas under development. A general point of view had to be developed to the effect that knowledge of building, function, and comfort had to be considered in a larger connection. Resources, production, consumption of energy, and handling of waste products became the factors which governments (legislation), R&D laboratories, and official and industrial research centers had to take into account.

How this has been achieved in some of the 19 REHVA countries will be discussed, using actual projects to show how various governments and organizations have tackled the matter.

Challenges Facing Manufacturers of IAQ Equipment

D. G. Rich, Past President of ASHRAE, Carrier Corporation, Syracuse, NY, U.S.A.

Public awareness of environmental issues and public concern about the effect of the environment on human health has never been greater. While the outdoor environment continues to be of concern, increasing attention is being focused on the indoor environment as buildings have been made tighter, ventilation rates have been reduced, and more information has become available on the presence and effects of indoor contaminants. With this growing awareness and concern has come an increased demand for indoor air quality (IAQ) products and services.

Tapping the large and growing market for IAQ products provides opportunities and chal-

lenges for equipment manufacturers. It also poses risks. The opportunities and challenges are the same as those for any new or growing market: to identify customer needs and the types of products that can best meet these needs at an affordable price. The risks are that customers may expect more from these products than the products can provide, or—in the worst case—more than they have been led to believe they can provide. In the case of IAQ products, where expectations related to health may be involved, this could expose manufacturers to product liability claims that could have financially devastating consequences.

ASHRAE has long played a key role in IAQ. ASHRAE Standards will be briefly reviewed, together with their status of acceptance by model code organizations. The presentation will conclude with a discussion of the impact that ASHRAE Standards and ASHRAE research can have on stimulating responsible growth of the IAQ equipment market.

Fundamental European Documents on Energy, Hygiene, Health and Environment and the Future European Standardization

J. Uyttenbroeck, Centre Scientifique et Technique de la Construction (CSTC-WTCB), Brussels, Belgium

The design of a healthy building should meet the requirements of comfort and hygiene. It should also result in a building with low energy consumption. With regard to the single European market of 1993, these goals ask for a lot of European harmonization of standards. The presentation describes how, on the basis of the Construction Products Directive (1988), the fundamental documents (or interpretative documents) have been prepared especially for Essential Requirements No. 3 ("Hygiene Health and Environment") and No. 6 ("Energy and Heat Retention"). These fundamental documents will form the basis for giving mandates to the European Committee for Standardization for the preparation of all needed standards. An example of such a mandate will be given.

New European Guidelines for Ventilation Requirements in Buildings

P. O. Fanger, Technical University of Denmark, Lyngby, Denmark

The new European guidelines recommend the ventilation required to obtain a desired indoor air quality in a space. The first step is to decide the air quality wanted in the ventilated space. A certain air quality is prescribed to avoid adverse health effects, but a decision is required on the level of perceived air quality aimed for in the ventilated space. Three different comfort levels are suggested.

The next step is to determine the pollution load on the air caused by pollution sources in the space. In contrast to previous standards and guidelines, all pollution sources are acknowledged. The total pollution load is found by adding the loads caused by the occupants and by the building, including funishing, carpets, and the HVAC system itself. The ventilation rate required to provide the desired indoor air quality is then calculated based on the total pollution load, the available outdoor air quality, and the ventilation effectiveness. The ventilation rates required for health and comfort are calculated separately, and the highest value is used for design.

The new European guidelines provide a strong incentive to use low-polluting materials in buildings. If such materials are not used, the new guidelines prescribe higher ventilation rates than most previous standards and guidelines.

State of the Art and Prospects for Raising the Efficiency of Ventilation and Air Conditioning Systems

M. I. Grimitlin, Research Institute of Occupational Safety, St. Petersburg, Russia

In recent years, along with sanitary-hygienic and social concerns, more importance has been attached to economic aspects due to increased energy consumption by ventilation systems. Energy balance analysis performed at many industrial enterprises has proved that the average share of ventilation and heating load in their total heat consumption is approximately 30%, and is as much as 50% in the machine-building and instrument-engineering sections. In spite of enormous investments in material, energy, and labor resources, sanitary-hygienic efficiency of the ventilation systems is still low.

Wide adoption of local exhaust systems in industry is the most cardinal and effective way of increasing sanitary-hygienic and energy-saving efficiency of industrial ventilation systems. When using this method of ventilation, the amount of harmful matter removed with every cubic meter of extracted air is dozens to hundreds of times larger than in the case of general exchange ventilation.

Over the past few years considerable progress in the development of methods of designing general exchange ventilation and air distribution systems has been made: investigation of ventilating jets has taken into account the peculiarities of their development in enclosed spaces; a principle for a complex (simultaneous) solution to the problem of finding air exchange and air distribution parameters, based on the regularities of jet flows and on approximate mathematical models of heat and air motion process in ventilated spaces, has been proposed; and the expediency of controlling air flows for the purpose of optimizing heat and air consumption throughout the year has been shown.

In recent years a number of new methods of air discharge have been proposed and implemented in our country which include air supply using directed jets, inclined jets, "flooding" of the occupied zone, air supply through floor mounted panels, discharging whirl jets, and vortex and direct-flow delivery.

Data on the actual situation and prospects for producing ventilation and air conditioning equipment in our country are given. We emphasize that for a successful solution to the problem of improving the quality and reliability of the manufactured ventilation and heating equipment it is necessary to fundamentally reconstruct the existing enterprises. Producers of ventilation equipment are inviting foreign investors for this purpose. Companies belonging to the defense industry must be drawn into the production of ventilation equipment within the framework of the conversion campaign carried out in Russia, and extensive support must be provided to the newly setup companies and joint ventures whose responsibility, along with manufacturing ventilation equipment, is to produce turnkey installations.

Poster Viewing Session: 10:15-11:00

Session One: 11:00-12:30

The Environmental Challenge Faced by Air Conditioning

L. Lucas, International Institue of Refrigeration, Paris, France

This paper will summarize problems that have arisen and the initiatives taken to respond to them. Efforts to raise living standards in both developed and developing countries are creating, at once, greater environmental concerns and greater demand for air conditioning. Air conditioning often requires substantial energy, as well as the use of chlorinated fluorocarbons (CFCs) in the cooling systems and the insulation, quite separate from the sanitation problems that it presents.

Hence, designers, clients, citizens, and governments must evaluate the choices anew and reflect on the benefits and drawbacks to everything from short-term effects on health to long-term ecological equilibrium. Local efforts should be pooled and experience shared to meet this new challenge with full force. This presentation will illustrate what is being done to achieve these goals and how actions are being organized.

Asthma and the Home Environment

D. Norbäck, J. Widström, C. Edling, E. Björnson, C. Jansson, and G. Boman, University Hospital, Uppsala, Sweden
U. Palmgren and G. Ström, Pegasus Labs, Uppsala, Sweden

A worldwide investigation of the prevalence of allergies, asthma, and bronchial hyperactivity is in progress within the European Commission Concerted Programme (EC Respiratory Health Survey). As a part of this study, a population based case-control study was performed in the Swedish community of Uppsala. The study comprised 45 adult subjects with asthma symptoms, a random sample of 44 subjects with asthma symptoms, and a random sample of 44 subjects without such symptoms. Room temperature, air humidity, volatile organic compounds (VOCs), respirable dust, CO_2, viable molds and bacteria, and total concentration of airborne microorganisms were measured in the dwellings (CAMNEA method). Presence of house dust mites in settled bedroom dust was also investigated by the semi-quantitative Acarex-test.

Mites were significantly more common among subjects with asthma symptoms than among controls ($p = 0.04$). No significant relation between asthma and formaldehyde, molds, or bacterias could be demonstrated. Only about 1% of indoor bacteria and molds in dwellings are viable.

Mites are frequently found in dwellings in mid-Sweden; this can be explained by the fact that indoor air humidity is often above 30% RH even during the winter. There also seems to exist a relation between mites in dwellings and asthma. Possible relations between asthma and other indoor exposures will be analyzed.

Indoor Air Quality and Sick Building Syndrome in 27 Air Conditioned Offices: The Effects of Five Smoking Policies

A. Hedge, W. A. Erickson, and G. Rubin, Cornell University, Ithaca, NY, U.S.A.

The effects of five different smoking policies on indoor air quality in 27 air conditioned office buildings will be described. The five smoking policies studied are smoking prohibited, smoking restricted to rooms with local filtration, smoking restricted to rooms with no local air treatment, smoking restricted to rooms with separate ventilation, and smoking restricted to the open-plan cubicle workstations and enclosed offices. Concentrations of carbon monoxide, carbon dioxide, respirable particulates, formaldehyde, ultraviolet particulate mass, and nicotine, as well as air temperature and relative humidity, were measured in each building.

There were no significant differences among policies for numbers of smokers or average number of cigarettes smoked daily or for levels of carbon monoxide, carbon dioxide, respirable particulates, relative humidity, air temperature, or illumination. There were significant differences among policies that spatially restricted smoking within a building. The highest concentrations of these contaminants were found under the policy to restrict smoking to rooms with local filtration. Levels of ultraviolet particulate mass, formaldehyde, and nicotine were significantly higher in smoking rooms than in nonsmoking office areas among policies that spatially restricted smoking within a building. A questionnaire survey of 4479 workers in these buildings showed that complaints were not influenced by smoking policy and were not correlated with the indoor air quality measures taken, but they did correlate with occupational and personal factors.

Simulation and Emulation Methods in Design, Commissioning, and Operation of HVAC Sysems

R. Kohonen, J. Hyvärinen, and P. Laitila, Laboratory of Heating and Ventilation, Espoo, Finland

Three main phases can be distinguished in the life cycle of a building: design, construction, and operation. Energy efficiency is influenced by solutions found during these phases. The paper discusses the use of simulation and emulation methods for design, commissioning, and operation phases based on the results of the Finnish National Energy Research Programme LVIS-2000 and the International Energy Agency (IEA) collaboration.

The first step in the realization of HVAC systems is to define functional requirements for the systems. A systems approach has been developed to analyze the functional performance of HVAC systems. The paper demonstrates that through a systematic simulation analysis, an optimal control strategy of variable-air-volume (VAV) air conditioning systems can reduce energy consumption by 50% by maintaining the predicted percentage of dissatisfied index for thermal comfort under 10%.

An emulator is a testing facility for HVAC control systems and energy production equipment. An emulator can be utilized in tuning and in performance testing of automation equipment in the commission phase, as well as in training the building's maintenance personnel. In this paper, the structure of an emulator and the ways it can be used are described. In addition, a testing procedure for HVAC control systems using the emulator is presented. The usage of the emulator and the testing procedure is demonstrated with an analysis of a supervisory control strategy of a VAV air conditioning system done within the IEA collaboration.

The longest period in a building's living cycle is the operation period, during which the most energy is consumed and the indoor environment should be kept within allowable limits. Building optimization and fault detection (BOFD) seeks to detect and locate the unfavorable operation of the building's mechanical systems and the building itself in terms of energy consumption and indoor environment quality. A BOFD system concept using real-time simulation methods is described, and the motives and drives for implementing such a system to support the optional operation of HVAC systems are discussed. A fault detection method for heat exchanges also is introduced.

Commissioning: From Theory to Practice

J. P. Laurent, AIB-Vincotte, Brussels, Belgium

The quality of the indoor environment and the well-being of occupants are sometimes subjective and sometimes objective sensations. The design, the construction, and the operation of buildings require a specification of criteria which are subsequently expressed in different parameters and commitments that should be integrated into construction specifications.

In addition to a systematic conformity examination, measurements are necessary to evaluate a situation or a building, to quantify the complaints of the occupants, and to approve the technical installations or the building. It should be possible to verify the objective parameters. The investigators require a precise definition of the objective parameters to be measured, the evaluation criteria to be used, the measuring techniques to be used, and the measuring procedures to be applied. These four elements must be defined bearing in mind the particularity of a building and a reasonable cost. Our experience convinces us that much work remains to be done in the field of nonphysical parameters.

Checking the objective parameters—physical parameters among others—also requires that the building and the technical installations be designed in such a way that the measuring method and procedures to be used can be applied. Our experience tells us that this is not often the case; measurements must be carried out under all conditions. International regulations and codes should compel the designers to respect the requirements of the measuring procedures.

Poster Viewing Session: 12:30-13:00

Session Two: 14:00-15:30

Risks Associated with Mineral Fibers in Offices

J. Bignon, L. Martinon, M. A. Billon-Galand, and P. Brochard, Université Paris XII, Creteil, France

In recent times, asbestos-containing materials have been widely used in offices, both for their fire-retardant properties and for insulation protection. Over time, their degradation releases microfibres into office air, which creates an indoor pollution that must be evaluated with respect to possible effects on human health. In fact, it is actually established that exposure to high concentrations of asbestos, as was the case 10 years ago, represented a real lung and mesothelium cancer risk to workers.

The problem with asbestos office pollution is knowing which dosage levels and which types of asbestos we are dealing with. Among asbestos types, one must be able to distinguish the chrysotile, the most widely used and now seriously regulated variety, and the amphiboles (amosite and crocidolite), varieties that were much less used and which are actually banned. While these varieties have nearly identical biological effects on cultured cells and small rodents, epidemiological studies have shown that, in man, exposure to chrysotile is less often associated with lung and mesothelium cancer than with amphiboles.

The occupants of offices containing asbestos based materials must be placed in three categories:

- C1: general occupants that inhabit the office daily for a significant amount of time
- C2: janitorial or cleaning personnel engaging in activities that may liberate or recirculate asbestos fibres
- C3: maintenance workers and exterior personnel that operate on the level of asbestos installers.

Categories 2 and 3 can be subject to occupational type exposure. In contrast, the risks encountered by the C1 occupants are poorly defined, justifying current concern and the Health Ministry's recommendations.

Measurements of asbestos fibers in offices, notably those of LEPI in Paris, show clearly that air concentrations of fibers are very low, generally under 0.2-2 f/L (0.0002-0.002 f/mL). Recent

mortality studies on asbestos worker cohorts exposed to concentrations no higher than 1 f/mL did not show any excess cancer at these concentrations. Under these conditions extrapolating the cancer risk observed in historical cohorts exposed to high doses, often under-evaluated, permits the calculation of insignificant cancer excess compared to other daily risks to life.

Synthetic fibers have increasingly been used in place of asbestos as building insulators. Mineral wools are actually most used in insulation. Fibers are large, with diameters greater than 1 or 2 microns, of which only a small percentage is breathable (susceptible to alveolar deposition). These reasons and the rapid dissolution of such fibers in the lungs explains that one can consider the health risks of such insulation materials in buildings to be minimal.

Estimation of Risks for Indoor Exposure to Environmental Substances

T. D. Sterling, J. J. Weinkam, and W. S. Rosenbaum, Simon Fraser University, Burnaby, BC, Canada
C. W. Collett, Theodor D. Sterling and Associates Ltd., Vancouver, BC, Canada

Measures to control possibly hazardous or unwanted substances in public or commercial buildings as well as residences depend heavily on methods by which risk of exposure to such substances are determined. Two major approaches have been used: extrapolation from high to low dose of exposure and epidemiologic studies that determine if there is an elevated risk for exposed individuals, using unexposed individuals as referents. Two important examples are the recent risk assessment of exposure to environmental asbestos fibers (EAF) by the Health Effects Institute Asbestos Research in conjunction with the U.S. Environmental Protection Agency and lung cancer risk assessment of building occupants exposed to environmental tobacco smoke (ETS), also by the U.S. Environmental Protection Agency. In practice the extrapolation and epidemiologic approaches appear to result in risk estimates which differ substantially. The risk estimate based on extrapolation is considerably smaller than the risk estimates based on epidemiologic studies. Suitability of each method of risk estimate for EAF and ETS (and other possible substances) and reasons for differences between them will be reviewed.

Advanced Workplace Demonstration Project

V. Hartkopf, V. Loftness, S. R. Lee, A. Mahdavi, and J. Gauchel, Carnegie Mellon University, Pittsburgh, PA, U.S.A.

The Center for Building Performance and Diagnostics at the Carnegie Mellon University Department of Architecture is designing and constructing an "office of the future" environment, which will function as a teaching and research facility for building performance and diagnostics as well as an actual working office. The facility will contain an array of high-performance assemblies in such areas as the mechanical system, electrical system, telecommunications system, and interior furnishings system.

"The Intelligent Workplace" will function as a testbed for research in building performance and will demonstrate innovations ranging from responsive thermal load balancing to advanced workstation concepts. These innovations will be interchangeable, allowing for the future study of more advanced generations or entirely different types of system components as they become available. More importantly, the research program at the facility will focus on how these integrated components affect building performance. Advanced sensing, actuating, and control instrumentation for monitoring building performance is integral to this research. This work is being sponsored by the Advanced Building Systems Integration Consortium (ABSIC), a university-industry consortium of 10 U.S. leaders in the building industry, along with Carnegie Mellon University and the National Science Foundations.

Detecting Acute Toxicity of Product Emissions by ASTM E-981

R. C. Anderson and S. Hopkinson, Anderson Laboratories, Dedham, MA, U.S.A.

Is it possible to detect acutely toxic product emissions which contribute to indoor air pollution? If so, the data would facilitate source control through product selection. A commercial product associated with sporadic health complaints was studied. Group 1 (eight products) was purchased locally; Group 2 (nine products) was submitted by individuals attributing indoor air quality (IAQ) health problems to the product.

Each product was sealed into an individual glass chamber and heated to 37°C. Irritant potency of the emissions was measured with ASTM E-981. Male Swiss Webster mice were exposed (head only) to the emissions during four successive one-hour tests. Animals were electronically monitored for irritant effects (respiratory changes). Neurotoxicity, body weights, and survival were recorded.

Some Group 1 animals showed mild behavioral and respiratory changes after exposures one and two only. The Group 2 animals exhibited pulmonary irritation and progressively severe neurological effects (gait, grip, paralysis) with sequential exposures. Deaths occurred in eight of nine cases. The chemical mediator of these severe effects is unknown. We conclude that this method is capable of discriminating between products on the basis of emission potency; application of this test could improve IAQ by detection and avoidance of sources of potent irritants.

Radon Reduction in Buildings: The Case of Two Belgian Schools

P. Cohilis, P. Wouters, and P. Voordecker, Centre Scientifique et Technique de la Construction (CSTC-WTCB), Brussels, Belgium

Various investigations were performed in two Belgian schools presenting high radon concentrations in order to define appropriate remedial actions. These investigations included a detailed visual inspection of the buildings, tracer-gas experiments, pressurization experiments, and CO_2 and radon concentration measurements. As a result of these investigations, a mitigation system was proposed for each school. The classroom pressurization technique was used in one of the schools, while the crawlspace ventilation method was applied to the other one, after the sealing of some radon entry routes.

The use of these two methods was completely successful in achieving radon reduction. For the first school, the possibility of using a subslab depressurization system was also evaluated with success, but the room pressurization method was preferred because of its ability to improve the general indoor air quality of the classrooms. For the second school, the choice of the method based on the ventilation of the crawlspace was dictated by the simplicity of the method. When possible, this type of argument should be taken into account while defining an appropriate mitigation method for a building. But, of course, the most important argument is a high probability of success for the reduction of the radon concentrations. From this point of view, the present study indicates that the knowledge of the air tightness characteristics of the building and of some particular rooms is important.

Poster Viewing Session: 15:30-16:00

Session Three: 16:00-18:00

Indoor Air Microbial Contamination in Perspective

R. Rylander, University of Gothenburg, Gothenburg, Sweden

Bacteria and molds are ubiquitous in man's environment and are usually tolerated without adverse reactions. When the exposure level increases, inflammation and sensitization will appear. In well constructed houses with heating and adequate ventilation, conditions for multiplication of microbes are poor. Increased humidity caused by leaking roofs, burst water and sewage pipes, or poor ventilation favor the growth of molds and, if pools of water are present, of gram-negative bacteria. Molds and gram-negative bacteria contain biologically active substances—(1 to 3)-ß-D-glucan and endotoxin respectively—which have been related to pulmonary problems and general symptoms among persons in problem buildings.

The presentation reviews investigations on microbes in indoor air and studies on the relation between exposure to microorganisms and symptoms. It suggests that exposure to inflammatory

and antigenic substances derived from microbes is a major reason for indoor air related symptoms.

Design and Application of an Upward Plug Flow Ventilation System

H. G. Burnley, Jr., Phillip Morris Inc., Richmond, VA, U.S.A.

By using an innovative combination of existing HVAC technologies, a displacement ventilation system has been developed and field tested. With plug flow ventilation, measurements in a simulation room and commercial installations have revealed improvements to recognized parameters of acceptable indoor air quality.

A simulation room was first constructed for the purpose of testing a variety of air distribution methods. The system that demonstrated the most effective results consisted of a raised flooring system with perforated metal plates covered with porous carpet. Supply air below ambient temperature (20°C) was supplied from ducts below the perforated flooring, rising in a vertical pattern to displace the warmed room air. In the simulation room, the return air flowed through an electronic air cleaner to remove more than 80% of the respirable suspended particles. The air then passed through an acid-treated activated carbon filter to remove gas-phase components. The treated return air was then mixed with outside air. The filtered air was then drawn through conventional heating and cooling coils to adjust its temperature.

A comparison of three indoor air quality parameters was conducted to test ceiling versus floor introduction of supply air. Results from tests conducted in the simulation room revealed reductions in three parameters compared to conventional ventilation: airborne particulates (reduced from 0.93 to 0.1 mg/m^3), nicotine (decreased from 0.26 to 0.015 mg/m^3), and ammonia (decreased from 0.53 to 0.07 mg/m^3).

The same design guidelines were employed for construction of a displacement ventilation system in the lounge of a performing arts center. Tests at the breathing zone during actual occupancy revealed values of carbon dioxide, carbon monoxide, formaldehyde, nicotine, RSP, volatile organic compounds, and microorganisms lower than in conventionally ventilated rooms. Temperature and relative humidity levels were consistent.

Health Requirements Related to Building Design and Technology

C. Molina, University Hospital, Clermont-Serrand, France

In anticipation of the single European market in 1993, a European Economic Community directive (89-106) defines six requirements applicable to both buildings and civil engineering works to remove all barriers to the free circulation or use of construction products. Among these, a document set up guidelines on "Hygiene, Health and Environment".

Health requirements related to conception of the building and failability of materials include: location of building (radon, noise), materials and products (asbestos bricks, performance, and life cycle), and off-gassing of products [formaldehyde, volatile organic compounds (acaricide paints)].

Health requirements related to use and flexibility of premises include indoor air quality (safety, comfort, and quantitative risk assessment), which depends on physical factors relevant to technical measure, chemical factors improved by increase in ventilation (environmental tobacco smoke and recent French legislation), and biological factors such as bioaerosols (allergens, molds, and bacteria).

Maintenance concerns, especially with regard to HVAC systems, also will be discussed. We will discuss the general hygiene of a building (e.g., rodent and cockroach control, which are vectors of disease) and especially the supervision of the HVAC system. The prevention of Legionnaire's disease, hypersensitivity pneumonitis, and Monday fever also will be discussed. A report of two personal surveys in France will show how to help prevent sick building syndrome.

In conclusion, it will be shown that harmonized standards, European and international technical approval, and interdisciplinary cooperation between architects, engineers, designers, and doctors will help to overcome these problems.

Energy Implications of Comfort Standards

D. J. Croome, G. Gan, H. Swaid, and H. B. Awbi, University of Reading, Reading, UK

This paper deals with the energy saving potential of comfort conditions in offices. Physical measurements and subjective assessment have been carried out to evaluate the thermal comfort in offices. The results indicate that the comfort temperature in offices is lower than that given by the current standards based on Fanger's comfort model. According to this and other field studies, there is a substantial potential for saving energy in space heating by lowering room temperature from the currently recommended thermostat setting, by effective use of clothing in cold seasons, and by individual control of the local environment.

Primary Prevention of Indoor Air Quality Problems in the New Conoco Building

F. Gaute, ISIAQ, Stavanger, Norway

Efforts have been focused for decades on low investment cost and energy consumption. After the oil embargo in the mid-1970s, several energy conservation efforts have had a negative impact on indoor air quality. This unfortunate situation may be about to change because of better documentation on the effect on humans of an adverse indoor climate in an ongoing Norwegian project. The preconstruction phase of the project included an unprecedented feature (at least with respect to Norwegian projects of a similar type), the preparation of an Environmental Plan. The purpose of this plan was to define the environmental objectives of the project, considering both the workplace (internal) and natural (external) environments.

A principal objective was to create a standard for internal environmental quality that far exceeded the usual occupational health and safety considerations in all areas, particularly with respect to air quality. No previous project in Norway has implemented such an intensive program to maximize internal air quality. The specification was not limited to materials; it also included building and cleaning procedures and other factors that might have a negative influence on indoor air quality after occupancy.

The building was occupied in March 1991, and so far there have been no severe complaints about the indoor environment. Investment costs and energy costs are negligible in comparison with wage-related costs, and the total costs are low compared with similar office buildings.

Ecology and Allergenic Significance of Domestic Mites

F.T.M. Spieksma, University Hospital, Leiden, The Netherlands

Among the many organisms which can be elements in the indoor human environment, domestic mites take a constant and prominent position. They do so because they are specialized as coinhabitants of the human "nest". Within the group of domestic mites, one might distinguish two ecologically defined subgroups: house dust mites and storage mites.

House dust mites are those members of the family *Pyroglyphidae* that have been found more than incidentally in human dwellings (approximately 10 species). They are the really specialized human nest dwellers, living on the keratinous scales shed from the human skin, thereby playing an essential role in a biological recycling process. Their primary location is in beds and stuffed furniture, but extensive colonization towards floor dust is taking place, particularly during the warm and humid summer season in temperate climates.

Storage mites living in homes might be considered secondary inhabitants since they live on stored and waste-food materials. In fact, they are better known by their damaging effect on stored food in flour mills, bakeries, and farms. They include several families and many species.

All mites are potential producers of sensitizing, allergenic substances, causing respiratory disorders in sensitive people. The most effective and long-lasting measures against them are cleaning, prevention of water penetration, and ventilation to expel excess of water vapor.

Comparative Indoor Air Quality Demand Control Strategies for VAV Systems in Temperate Climates

M. Meckler, Meckler Engineers Group, Encino, CA, U.S.A.

Heating, ventilating, and air conditioning (HVAC) systems with variable-air-volume (VAV) flow control respond to net space demands for heating or cooling, or both, by introducing more or less air into an occupied space. As a result of reduced airflow rates when low thermal loads are encountered, indoor air quality (IAQ) can suffer. In a conventional VAV design, this problem is countered by introducing dilution air. But total reliance on dilution air is neither energy efficient nor cost effective and may, in fact, aggravate IAQ problems in buildings located in the growing number of urban settings that are already unable to satisfy the Ambient Air Quality Standards.

The design strategy employed here involves the use of a carbon dioxide (CO_2) sensor(s) for a ventilation demand-driven system capable of maintaining CO_2 levels without sacrificing comfort and of significantly reducing energy consumption since CO_2 is now widely recognized as both a surrogate for odor and as an indirect measure of the adequacy of mixing outdoor and recirculated air. This paper will present the results of an office building study using an HVAC computer load estimation program having an algorithm capable of estimating time for varying CO_2 concentration levels.

Another design strategy that can be employed is the use of a supplemental, high-efficiency filter/air cleaner in a VAV by-pass loop. The system utilizes minimum outside air (15 cfm/person) with demand control (30% air). This system provides a thermostat in every comfort zone, which allows the system air damper to carefully monitor and control the temperature of each zone that is most comfortable to the occupants. Should any zone require additional ventilation control due to a rise in space contaminant levels, the system will increase the supply air temperature, thereby automatically allowing more air to be by-passed to the high-efficiency filter/air cleaner cartridge to increase system source removal capability.

As a result, cleaner air is supplied to the occupied zone whenever the supply air-flow rate is reduced during the VAV mode of the system. Mathematical analysis shows that the by-pass flow should not exceed one-third of the system flow. The analysis also indicates IAQ actually deteriorates if the by-pass air flow exceeds one-third the system flow, even with a 100% efficient system methodology of the model along with a representative example. We will also compare the dilution air strategy described above with the strategy of using a high-efficiency filter/air cleaner in a VAV by-pass loop.

Posters

Airborne Levels and Particle Size Distribution of Cat Major Allergen Following Use of Anti-allergic and Standard Vacuum Cleaners

F. deBlay, A. Vérot, M. Ott, F. Frey, and G. Pauli, University Hospital of Strasbourg, France

Recently, manufacturers have marketed very expensive vacuum cleaners (VC) as "anti-allergic" devices. We compared five different VC. The three "anti-allergic" VCs were: HEPA Filter VC (HEPA), water impingement plus HEPA VC (WI), and a fabric-foam filter VC (FF). The two remaining vacuum cleaners were standard models [standard VC (ST) and a VC chosen because of its inexpensive nature (INEX)]. Airborne samples were collected using an impinger in a 20-m^3 experimental room and in a 25-m^3 living room in a home with two cats. Air was sampled before, during, and immediately after vacuuming for 15 minutes at a flow rate of 17.5 L/min. Airborne Fel d I (a common cat allergen) was measured using a two-site monoclonal ELISA assay. The mean values (ng/m^3) and particle size distribution of airborne Fel d I obtained in the experimental room are shown in the table on this page. In all experiments no measurable airborne Fel d I was found prior to vacuuming.

The total mean values (ng/m^3) of airborne Fel d I in the home with two cats were 5.3 with HEPA, 6.7 with INEX, 72.8 with FF, 41.5 with ST, and 6.0 with WI. We conclude that allergists and patients should be careful about buying very expensive "anti-allergic" vacuum cleaners.

A New System of Hygrothermal Microclimate Nonuniformity Evaluation

M. V. Jokl, Tecnical University of Prague, Czechoslovakia

Nonuniformity of the hygrothermal constituent of the environment (NUN) has always been a problem in hot workplaces, especially in iron works and in glass works, where man has been exposed to excessive radiant heat from one side only. NUN also appears in lightweight buildings where large windows become the source of excessive radiant heat in summer (and even in spring and autumn) and the source of negative net radiation in winter. There also are cold draughts (i.e., excessive cooling by convection) in the interiors of air conditioned buildings and within buildings with forced (and even with natural) ventilation, which may result in painful backache (lumboischiadic syndrome).

Geographic Distribution of Radon in Southern Belgium: A First Approach

F. Tondeur, I. Gerardy, C. Licour, N. Medaghri-Alaoui, and N. Dubois, Institut Supérieur Industril de Bruxelles, Belgium

Approximately 800 radon measurements have been performed in buildings of the French-speaking part of Belgium by the charcoal canister method (3-4 day measurements). They are analyzed to describe the regional distribution of the radon risk and its relation with the nature of soils. A map of the radon risk shows a large region of elevated risk in the Ardenne region, associated with shale. A "hot spot" of similar nature is found in Brabant. Moderate problems are found north of the Sambre and Meuse rivers, usually on silty soils. Radon measurements directly in the soil with the alpha-tracks method and *in-situ* soil activity measurements by gamma spectroscopy also are used to analyze the radon source in different types of soils, confirming in particular the possibility that silts might be a significant source, although their low permeability probably limits the radon emanation in many cases.

The Gaz de France Experimental Building: A Unique Tool for the Study of Energy Systems

F. Massard, Gaz de France, La Plaine St.-Denis, France

One of the primary objectives of Gaz de France is the promotion of natural gas. Thus, its research center has invested considerable resources to perfect certain products and extend the application scope of existing technologies.

The most recent of the thermal studies laboratories installed on the Plaine St.-Denis site is an experimental building, inaugurated in 1986, which supplements the controlled environmental test chamber and the two experimental lodgings. Using these laboratories between the bench tests and the pilot operations is a rule, so it is possible to analyze equipment interactions with the local environment (building, installation, and room occu-

Stages	Size	HEPA	WI	FF	ST	INEX
1	3->10µm	<0.2	<0.2	3.8	2.5	0.6
2	1.5-10µm	<0.2	<0.2	0.8	<0.2	<0.2
3	>5µm	<0.2	1.7	<0.2	<0.2	<0.2
Parallel filter		<0.2	1.8	7.7	18.3	0.9

pation), which is vital for gaining knowledge of a product.

Made up of 25 flats, the experimental building complies with the French thermal regulations and is representative of newly constructed buildings. The flats are distributed over five levels, each comprising one three-room flat, two two-room flats, and two studio flats in which it is possible to simulate human presence by internal electrical supplies, the drawing of domestic hot water, and the closure of roller blinds actuated according to a predetermined procedure.

The building is fitted with more than 2300 sensors designed to qualify products in terms of energy capacity (consumption and efficiency), intrinsic operating characteristics (safety, reliability, user-friendliness), and thermal and acoustic comfort. The sensors are linked to a data acquisition and processing complex. A phase involving acquaintance with the tool and the determination of its intrinsic characteristics preceded the actual operation of the building in 1988. This phase focused on improving existing products, validating prototype equipment or new concepts, and determining new rules for the installation and sizing of heating and air conditioning systems.

Energy Recuperation and Increasing Energy Efficiency of a Building

S. Kajl, University of Quebec, Montreal, PQ, Canada

There are several methods for recuperating energy and increasing the efficiency of a building's HVAC system. One method is to use, in winter, an air conditioner as a thermopump. One such system, coupled in series with a solar system, is functional at the Ecole de Technologie Superieure in Montreal.

This system and the operational results over one year are presented. The recuperated energy is used to preheat the environment air as well as the domestic hot water. The system consists of two heat exchangers, one centrifugal refrigerating machine, and one water heating solar system. Two different phases are distinguishable in the system.

In summer, one part of the heat rejected by the cooling machine is recuperated and serves to preheat the hot water. The hot water preparation is completed by the Hxlar system. This installation consists of 38 m^2 of vacuum tube photothermic converters, as well as two 2300-L stocking balloons.

In winter, the cooling machine functions as a thermopump. It permits the recuperation of energy from evacuated air and can preheat, by approximately 12°C, 85 m^3/s of system air. The sanitary hot water preparation functions as in summer.

Efficiency analysis of the system is presented in terms of winter and summer performance. The high return of the cells and their functioning conditions contribute to the high performance of the solar water heating system. The relatively low internal return of such a system is offset by the benefits of using it as a teaching aid. Also, the energy savings gained by the thermopump action of the cooling machine are very interesting. One simple analysis of the energy expenses of the building shows that the system reduced gas consumption by 100,000 m^3 during the 1991-1992 winter.

Site Environmental Quality Measurements in Energy-efficient Buildings

B. L. Krieg, Pacific Gas and Electric Co., San Ramon, CA, U.S.A.

A large U.S. electric and natural gas utility is attempting to design, install, operate, and evaluate integrated systems of energy-efficient technologies designed to maximize energy efficiency. These integrated systems will be installed in facilities owned and occupied by the utility's customers. There are two major constraints on the energy-efficient design: the systems must have a payback of less than 30 years (consistent with power generation investment payback periods), and the systems must be acceptable to the utility customer. To determine acceptability, a variety of site environmental quality measurements are needed for indoor air quality, radon, power quality, noise, lighting quality, occupant thermal comfort, and occupant satisfaction. When the utility did a literature search to identify what measurements should be taken, it discovered little agreement within the scientific community on what to measure or even the best measurement techniques. The utility then convened a panel of experts to help identify the most cost-effective strategy for determining whether the environmental quality at a site is "acceptable" to the occupants or users of the site after installation of the integrated systems of energy-efficient technologies.

After extensive discussion over several months, the expert panel identified which specific environmental quality standards would be used and the specific measurement techniques to be used:

- Occupant thermal comfort
  ASHRAE 55-81, ISO 77-30
- Indoor air quality
  ASHRAE 62-89, OSHA, EPA, NIOSH
- Noise
  ASHRAE Noise Criteria
- Lighting quality
  IES Lighting Handbook
  Application Volume 1987
- Power quality
  ANSI C84.1, IEEE 519, IEC 555
- Occupant satisfaction
  ASHRAE 55-81
- Radon
  EPA.

The specific measurement techniques and reasons for their use are documented in Site Environmental Quality Assessment procedures, which will be used at all residential and commercial demonstration sites.

Integration of Dehumidification into Life-cycle System Design

A. Shaw, R. E. Luxton, and P. G. Marshallsay, University of Adelaide, Australia

When designing an air conditioning system, commercial and physical parameters must be determined and many variables accommodated. The nonlinearities in the interdependencies between them are significant. A system that gives excellent performance at one of the infinity of possible combinations of internal load and external weather may produce unacceptable conditions at some other seemingly more benign combination. No designer would select a dehumidifier to suit marginal weather conditions without also assessing its performance during the occasional periods when the heat load reaches its peak value. Yet few designers consider in depth how a system selected to satisfy those occasional peak loads will perform during the much more common load conditions. For instance, few realize that the temperature rise of the chilled water is greater during part load than during peak load operation and that the region of coil surface nearest the chilled water exit can reach a temperature greater than the air dew point temperature. The significance is apparent since the latent contribution to the total load tends to increase as the total load decreases.

An extensive study of the intensive properties of air passing through a dehumidifier coil has elucidated both independently and in combination each of the several factors that govern the thermodynamic process path of the air as it passes through a dehumidifier coil. The new insights so provided now allow detailed exploration of the design space through the use of rigorously based coil simulation software. Such explorations for several commercial buildings have confirmed the value of focusing on the total system before addressing component related constraints. As an example, pretreatment of outside air is a well known technique for assisting with ventilation load in humid climates. In this present paper, the authors describe and analyze a fully integrated system, applicable also to temperate climates, in which outside-air pretreatment contributes directly to offsetting room loads as well. The system is shown to reduce both capital and operating costs substantially and to result in improved indoor air quality.

Mite Allergy in a Cold Climate Among Occupants of Improperly Designed Factory-built Homes

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E. Fernandez-Caldas, Tampa, FL, U.S.A.
C. A. Alvarado, Monteray, Mexico
S. Gravesen, Copenhagen, Denmark

Improperly built homes (Tri-State) have moisture condensation which rotted the exterior plywood sheeting and caused mold growth. The occupants have a high frequency of chronic respiratory disease. We evaluated mite allergy in this environment, performed medical evaluations, obtained RAST tests to selected antigens in 219 occupants from 65 Tri-State homes. We measured Group 1 antigens from *Dermatophagoides pteronyssinus*

(DP1) and *farinae* (DF1) in carpet dust in 49 Tri-State homes and 26 control homes. In selected homes, we collected dust samples for mite antigen, mold identification, and personal breathing zone air samples.

Intradermal skin tests to DP1 and DF1 were positive at 50-AU concentrations, 32% and 23% respectively. RAST to DP1 and DF1 were positive at 20% and 24% respectively, and very strongly so. Carpet dust of unrepaired Tri-State homes had large amounts of DP1 and DF1, and repaired homes had less. A few control homes had large amounts of DF1. Some Tri-State homes contained mites of other genera, and some occupants had IgE antibody to *Lepidoglyphus* destructor. These levels were higher than homes in Baltimore, MD and Rochester, MN. Penicillium and cladosporium molds were abundant. Some subjects had positive skin tests or RAST tests to the molds. No positive RAST tests were found to rotten plywood or insects. Three of the homes were selected for carpet and air sampling. The occupant wore a portable battery operated personal sampler while vacuuming the house, making beds, or getting into bed and preparing to sleep. Samples were compared for Group 1 monoclonal antibody. Because of the small air volume of the task samples, quantification of Group 1 antigens was imprecise. We conclude that vacuuming entailed about a tenfold increase in exposure to mite allergen and making the bed or getting into bed about a hundredfold increase.

We conclude that mite allergy is a contributing cause of respiratory disease of these rotting homes. The tasks of vacuuming, bed making, and going to bed increase exposure to the airborne mite allergens.

A Method for Estimation of Building Laplace Transfer Functions from Detailed Thermal Models and Applications

A. K. Athienitis, Concordia University, Montreal, PQ, Canada

This paper presents a general computer method for estimating building Laplace transfer functions from detailed thermal models. These transfer functions can be used both for building thermal control studies and energy analysis. Room operative and air temperatures are determined with their respective transfer functions. Laplace transfer functions for the building are obtained by means of thermal network models that include both distributed parameter elements, such as thermal mass, and lumped elements such as room lightweight contents. For detailed models, for which an analytical solution is generally not feasible, the Laplace domain transfer functions are obtained through a modified least squares polynomial fit to the discrete frequency responses obtained by inversion of the system admittance matrix. Fourth order polynomials were found to provide accuracies of ± 1%. Laplace transfer functions also are used for HVAC system and control components, and transient thermal control studies are performed by means of an efficient numerical Laplace transform inversion technique. Applications are presented for radiant and convective heating systems.

Energy Conservation Through Double-glazed Building Envelope

V. Butala, P. Novak, and L. Pahor, University of Ljubljana, Slovenia

In Ljubljana (46° north latitude and 14.5° east longitude), a square-form office building was built with a length of 42 m, surrounded by a glass facade. There is a glass-roofed atrium in the middle of the building which serves as a garden in the winter. This paper describes energy conservation actions in the only double-facade building in Slovenia. A computer program for simulating the heat flows in buildings, the heat losses and gains, and impact of sun radiation has been used to evaluate temperature conditions inside the building. Based on actual conditions inside the building, an energetic analysis has been performed for this kind of facade. Specific attention has been given to finding out how convenient double-facade is if applied to business buildings, generally in the form of energy economization. An inquiry on microclimate working conditions during the year has been conducted to show how the work environment is influenced by a double glass facade.

Control of Exposure to Formaldehyde During Dissection Work by Means of a Local Exhaust Ventilation System

H. Kokotti, E. Häkkinen, M. Tapola, and P. Kalliokoski, University of Kuopio, Finland

Conventional dilution ventilation systems have been shown to not adequately protect medical students from exposure to formaldehyde (HCHO) during dissection courses. This paper describes a study to decrease formaldehyde levels by means of local ventilation. First, a lateral local exhaust system was built and tested. Even though this reduced the exposure levels sufficiently, the air flow required (700 L/s) was too high and disturbed the general ventilation. Therefore, a new system was built to provide a make-up air supply close to the breathing zone of the students.

First, flow directions around the table were examined using smoke. Flow rates were determined with a tracer-gas technique. The formaldehyde levels were analyzed both in the dissection room containing the table with local exhaust and in two dissection rooms with ordinary tables and dilution ventilation. The formaldehyde levels were measured both by stationary and personal samples during the dissection course work. The capture efficiency of the lateral exhaust proved to be 95-100%. The disturbance flows were eliminated when an exhaust flow rate was more than 300 L/s per table and a supply-air flow was 30-50% less than exhaust flow.

The levels of indoor formaldehyde during five different situations of dissection work varied. However, the difference between the levels of HCHO in three dissection rooms appeared to be quite stable. Background formaldehyde levels in the test dissection room were 40-90% less than those in others. The formaldehyde exposure of workers in the dissection room with the local exhaust was 50-90% less than those in others. The HCHO levels of stationary samples varied from 0.03 to 0.24 mg/m³ and of personal samples from 0.1 to 0.2 mg/m³ in the test room. Corresponding values in other dissection rooms varied from 0.24 to 0.56 mg/m³ and 0.4 to 1.7 mg/m³, respectively. In all situations, formaldehyde levels were significantly less in the test dissection room than in others ventilated with a dilution system.

A Case Study of Draught as the Single Cause of Thermal Discomfort in an Office Building

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More than 10% of the employees working in a 900-m² office reported mucous membrane irritation and an increased frequency of rheumatoid and respiratory illness. Formaldehyde and microbial aerosols were ruled out as possible causes. Air was supplied by two HVAC systems with air outlets in opposite walls. Predicted mean vole and predicted percentage of dissatisfied indices, temperature gradients, and mean air velocities at the adjusted air temperature (23°C) were within acceptable limits. However, determination of local turbulence intensities (T = 23-116%) showed that too many people were dissatisfied by draught (DR = 27%) under the given climatic conditions. We found the method of air supply producing two colliding streams of air to be the most plausible reason for this case of local thermal discomfort.

Industrial Air Protection at Work with Highly Toxic Substances

N. Z. Bitcolov, Research Institute of Industrial and Marine Medicine, St. Petersburg, Russia

The problem of air protection at enterprises dealing with highly toxic substances should be considered from two perspectives: the quality of indoor air of industrial premises under normal conditions and the protection of indoor air and the environment under accident conditions leading to the destruction of industrial buildings. The required level of indoor air protection may be estimated by the integral air protection coefficient, which is the product of air protection coefficient of each method. At work with highly toxic substances, the principle of directional air flow is used in workrooms of equipment zones. It is achieved by adequate arrangement of exhaust and blowing ventilation and its efficiency.

Planning of industrial premises by creating so-called clean and dirty zones makes it possible to ensure safety ranging from one to three orders, local ventilation from one to two orders. General ventilation has a very low safety ability, within one order.

The problem of outdoor air of enterprises under normal conditions is solved by using a number of measures: technology, equipment, industrial premises and their planning, and protection mea-

sures (ventilation, air purification, protection zone). The amount of contaminants allowed to be released into the atmosphere under accidental conditions in ventilation and air purification systems should be less than the maximum permissible.

We can conclude that it is advisable to have several independent filtration systems to provide safety through system redundancy under accident conditions.

Air-flow Models for Multizone Buildings: State-of-the-art Review

F. Haghighat, Concordia University, Montreal, PQ, Canada

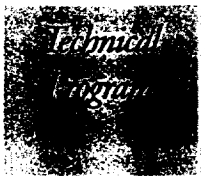
Several mathematical models have been developed to study air flow and indoor air quality in multizone buildings, and to develop control strategies. These models can be grouped into two categories: detailed models for predicting air flow and contaminant distribution patterns (room air movement models) and simplified models for the same predictions in buildings consisting of one or several "well-mixed" zones (building air movement models). Room air movement models are capable of predicting two- or three-dimensional air flow and contaminant distribution patterns in multizone buildings. Building and air movement models use a network approach. Nodes representing zones of differing pressure, temperature, and contaminant concentration are interconnected by leakage paths. Uniform and instant mixing is assumed for each zone. This paper first describes the methodology and then gives the capabilities, limitations, and assumptions of some of these models.

Alternate Refrigerants to HCFC-22 in Air Conditioning Applications

S. Kondepudi, Drexel University, Philadelphia, PA, U.S.A.

With the advent of the Montreal Protocol, there is considerable interest to developing alternatives to both chlorinated fluorocarbons and HCFCs. HCFC-22 is a common refrigerant used in air conditioning and medium-temperature refrigeration applications.

This paper presents experimental results obtained by using a blend of R-32 and R-152a in a residential air conditioning system and comparisons with results obtained from simulation. The cooling capacities were within 10% of that obtained with R-22, but the efficiencies were within 1% of that for R-22. Since the experimental work was a "drop-in" test with no hardware modifications or optimization, these results are seen to be encouraging, and further work is planned.



Study and Planning Definition of a Bioclimatic Office Building

G. Gatto, I. Meroni, and F. Scamoni, National Council of Research, Milan, Italy

In recent years, the study and development of the application of bioclimatic technologies for buildings have taken on a particular interest. This paper describes the results of a study which led to the general planning definition of bioclimatic office buildings. On the basis of experience acquired with experiments carried out on bioclimatic systems and components, the most suitable technologies for the definition of the project are outlined on the basis of the following requirements: (a) use of high-energy performance elements, components, and technologies; (b) a shape able to maximize the solar contribution; (c) thermal, visual, and acoustic comfort; (d) storage and conveyance of solar heat; (e) devices for automatic control; and (f) auxiliary climatization plants.

The paper also describes the results of calculations to verify the reliability of the design solutions proposed for the building.

Aquifer Seasonal Cold Storage Contributes to Improved Air Quality

A. Snÿders, G. J. Van Mourok, and H. Buitenhuis, Utrecht, The Netherlands

Aquifer seasonal cold storage has been identified as a technology that economizes on energy consumption for cooling buildings. During the winter, groundwater is pumped up from an aquifer (a thick sand layer), cooled with cold air from outside, and subsequently reinjected into the aquifer. In this way, a reservoir of cold water is created. Whenever there is a demand for cooling the cold water is pumped up and used for cooling. The heated water is then reinjected into the aquifer. Aquifer seasonal cold storage projects, following this principle, have been realized in The Netherlands in the cities of Amsterdam, Rotterdam, Eindhoven, and Gouda.

In the paper,the various configurations of cooling systems with seasonal cold storage will be described. From analysis of these cooling systems, it will be concluded that:

- Aquifer seasonal cold storage, or the combined storage of heat and cold, turns out to be a cost-effective technology or energy-efficient space cooling in many situations.
- Widespread application of this technology will result in significant reduction of the emission (as compared to the emission when using chillers) of gases that contribute to the greenhouse effect, acid rain, and ozone-layer depletion.
- For buildings in which cooling is entirely provided by ventilation air, the air-handling units can be used to load the store in the winter, while the ventilation air is simultaneously preheated. This system configuration allows for reduction of ventilation air recirculation, without increasing the energy consumption for heating.

Environmental Nuisances of Fuel Oil Burners at Different Regimes

J. Lebrun, P. Ngendakumana, F. Hore, Z. Zang, and B. Zuo, University of Liege, Liege, Belgium

Current laboratory tests of emissions from fuel oil boilers suggest that a significant reduction of NO_x emissions could be achieved by "derating" burner power. Many medium-size burners already are designed for two different power rates. When correctly used, these burners should work most of the time in cyclic mode between "off" and "lower" power states. However, these burners are often not used correctly.

Significant nuisances could be generated at each change from one combustion regime to another. These transient regimes also deserve more attention. The paper will present a synthesis of laboratory test results and proposals of future research. The necessity of a regulation "framework" also will be stressed.

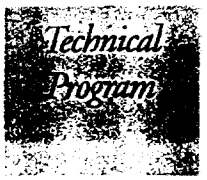
Indoor Air Quality, Energy, and Costs: Risk in Investment Decisions of HVAC Systems

T. Jedrzejewska-Selbak and B. A. Zawada, Warsaw University of Technology, Warsaw, Poland

There are a number of factors which affect the processes of indoor air quality formation in enclosed spaces. Some of them (building envelope characteristics, the type of HVAC system, and sources of energy supply) are selected during investment decisions and usually they cannot be changed during the construction of a building. Other ones (various periods of occupation, internal heat gains from production processes, daily variable outdoor climate) are simply disturbances.

Because there often is insufficient knowledge to undertake the correct investment decisions, the authors have carried out a test which makes it possible to estimate the risk of such decisions. The maintaining of indoor air temperature within permitted levels have been adapted as a quality criterion. The test has been run using a verified simulation computer program. As the input data, a set of measurements from a test industrial building has been taken. The analysis has evaluated the influence of changes of outdoor air temperature, energy supply parameters, quantity or air infiltration, and internal heat gains from production processes on the indoor air temperature.

The statistical method of analysis has enabled the selection of disturbances that have the greatest negative influence on indoor air temperature, and we can estimate the variations of temperature for a technical solution regarding HVAC systems.



Effect of Indoor Temperature Distribution on Energy Consumption in Ventilation Systems

A. M. Grimitlin, Ecoyurus-Vento, St. Petersburg, Russia

Saving energy in ventilation systems is one of our most pressing problems today. For its solution it is necessary to define the factors which influence the amount of consumed energy and to conduct qualitative and quantitative evaluations of the character of this effect.

For this purpose, relations for finding the amount of heat and cold consumed by ventilation and air conditioning systems are given in the paper. The annual cycle of the system operation is divided into three periods which are relatively close to the seasons of the year (winter, spring-autumn, summer periods).

The prime factor which influences the consumption of heat is indoor temperature distribution characterized by air exchange coefficient:

$$K_e = (t_{ex} - t_{su})/(t_{oc} - t_{su})$$

where

K_e = air exchange coefficient

t_{ex} = extracted air temperature, °C

t_{su} = supplied (incoming) air temperature, °C

t_{oc} = air temperature in the occupied zone, °C.

An analysis of the obtained formulae has shown that in winter and summer operating conditions one should try to increase K_e, whereas it should be reduced in autumn and spring.

Indoor temperature distribution also depends on a number of factors, the most important being the method of air distribution used. The necessity of varying K_e makes it advisable to design air diffusers that would allow us to control air-flow motion in a space and thus to obtain the required K_e value. Different grills equipped with devices for varying the direction of inflow air jets are an example of such an air distribution system.

On the basis of the introduced relationships, recommendations for the operation of air distribution systems depending on the outdoor climate variations have been worked out.

Analysis of the Global and Local Thermal Comfort Conditions due to Some Heating System Typologies

G. Rossi and M. Vio, Instituto Universitario Architetura, Venice, Italy

It is well known that global thermal comfort may be evaluated by means of predicted mean vole while the local thermal comfort is also due to a radiant symmetry. Taking into account these two thermal comfort parameters, plus the effects of different heating system typologies, an analysis of a rectangular room has been developed.

The air velocity (the outcome of the air's convective motion produced by every heating system typology) has been simulated by means of CLIS2D code. This code is based on the numerical resolution of Navier Stokes equations. Comfort limits are the same as those imposed or recommended by International Standards Organization Standards.

Heat Transfer Design of Building Envelopes in the Mediterranean Area Under Unsteady-state Conditions

F. Comair and G. Menguy, Université Claude Bernard Lyon, Villeurbanne, France

An experimental and theoretical study was conducted to improve the design of the building envelopes in the Mediterranean area. It was based mainly on two parts. The first part deals with the measurements of the thermal conductivity and diffusivity of some kinds of construction material (mortars, coatings, wall claddings, stones, etc.) and the influence of the volumic water content and volume mass on these characteristics. The second part deals with theoretical developments on the building envelope's capacity for heat transfer under unsteady-state conditions. The results of this investigation are presented with the necessary recommendations for design applications.

Improved Tenant Comfort and Energy Efficiency in Local-authority Apartment Complex Achieved Through a Retrofit Electronic Control System

P. Corcoran, University College Galway, Galway, Ireland

A pilot study to improve living conditions and energy efficiency has been undertaken in a local-authority apartment complex in Galway, Ireland. The study is unusual in that it demonstrates the benefits that may be achieved in older housing by retrofitting inexpensive electronic control systems.

In older housing such as the Galway complex, there is often no control or proper regulation on boilers on individual housing units. As a consequence, many units are significantly overheated, and tenants must regulate heat by the only means available—opening windows.

Under-floor heating is used in the Galway complex with central oil fired boilers feeding 24-40 individual units. A microprocessor out station was used to monitor temperatures and control solenoid valves in each unit. This was linked by modem to a remote personal computer.

Data gathered over a full heating season indicates a drop in average temperature of 3°C for the housing units studied. Combined with the reduction in infiltration losses—tenants in the controlled flats are more likely to keep their windows closed—this suggests that energy savings of up to approximately 30% might be reasonably expected in older housing through the application of retrofit electronic control systems.

First Experiences with the Utilization of the COMIS Software Package: A Multizone Air-flow Modelling System

S. Nowotny, intCom GmbH, Dresden, Germany

The COMIS software package, a multizone air flow and pollutant transport model, was first developed at Lawrence Berkeley Laboratory by an international group of researchers. The objective of the COMIS Model is to study air-flow distribution and pollutant transport in multizone buildings. With an interactive input program and graphical output option, COMIS is user friendly and easy to handle.

In the framework of the International Energy Agency, COMIS will be further developed to incorporate new physical knowledge and to help the user with default values for component leakage and pressure coefficients. Furthermore, an evaluation exercise will be performed using measured data. A sensitivity study will help the user to concentrate on the most important input parameters.

First experiences and problems that arose by collecting data necessary to run the COMIS software package will be demonstrated on an example of an office building.

Performance of a Heat-pump Ventilation Unit in a UK House

J. B. Siviour and M. P. Bertinat, E. A. Technology Ltd., Chester, UK

The overall objective was to find out how well a Scandinavian heat pump ventilation unit would perform in the UK. The performance of the unit was first measured in the laboratory under simulated UK winter conditions. A unit was then installed in a vacant house with simulated occupancy and operated through an actual UK winter. The data obtained form the basis of design recommendations for the use of such units in the UK.

The house used was a three bedroom, semi-detached with a floor area of 86 m² thermally upgraded to give a design heat loss of 2.8 kW at -1°C (significantly better than current UK building regulations) using only established techniques and construction methods.

The laboratory tests indicated that the heat output of the unit would meet 40% of this design heat loss, and that, taking free heat into account, the unit could supply over 80% of the total heating requirement during a typical UK winter. The house tests showed that supplementary heating is best provided to individual rooms, that great care must be taken in insulating all external ducting, and that in mild weather the bedrooms tend to overheat because of the different balances required for heating and ventilation.

Consideration of the Elderly in Design

R. G. Gregoire, Alternative Resource Management, Inc., Hebron, CT, U.S.A.

We frequently make use of heat loss analyses, average air flows, design temperatures (both inside and outside), and, once in a while, comfort

tables. ASHRAE comfort tables often refer to an "average man". However, as that average man ages from 20 to 70, his maximum energy capacity decreases by nearly 42%. In our work with people living in housing projects for the elderly throughout the state of Connecticut, we have observed many points of interest. Some of these should receive special scrutiny when applied to the elderly. Connecticut's temperate weather generates temperatures that vary from 3055 C-days (5500 F-days) to 4220 C-days (7600 F-days) annually.

Our paper will present observations made while working with approximately 1500 elderly (age 60 and above) persons. We will concentrate our discussions on a variety of design considerations which, while affecting the elderly person's quality of life, also have energy implications. Space heating requirements may be lowered at the same time that resident comfort is improved. Thermal insulation and air infiltration are two major points of concern. In the design stage, floor construction is of importance. Lower-cost concrete slab construction is the norm, yet their heat loss rates are typically higher than a well-insulated floor above a crawlspace or full basement. We will present common methods of remediation for existing facilities and offer empirical data regarding associated comfort.

Domestic hot water use can be altered by changing flow rates. We will study how the lower flows affect people's perception of temperature and comfort. In addition, the placement of bathtubs, inside versus outside walls, will be included in the discussion. Finally, lighting is an area which can provide either great satisfaction or consternation. Failing eyesight is a common problem of the elderly which calls for more illumination. The advances in energy-efficient lighting can provide the increased light output while saving energy.

We are convinced that comfort levels for elderly people can be enhanced in new and existing housing through simple methods, both in design and in remediation. In addition to improving the quality of life these techniques also save energy and money.

Lighting Quality and Lighting Efficiency: Providing an Empirical Basis for Lighting Standards

J. A. Wise, Pacific Northwest Laboratory, Richland, WA, U.S.A.

This paper reports mid-term results of a major Department of Energy (DOE) study that assesses the impact on lighting quality of lower lighting power density levels (lpd in W/ft²) under consideration for DOE's commercial building energy standard. This standard sets energy performance requirements that are mandatory for federal buildings and voluntary for the private sector.

The impacts on lighting quality have been contentious for years in discussions on progressive energy standards. Since lighting utilizes 40-60% of the energy budget of a modern building, there are significant energy savings available if lighting can be lowered without undue effects on occupants. Professional opinions range from quality issues being irrelevant for energy-efficient lighting to warnings that arbitrarily lowered lighting power densities can severely constrain lighting designs meant to provide the proper lighting for users of new schools, health-care settings, and computerized offices.

This assessment engages a multipronged approach to review laboratory and field evidence, conduct focused research, and combine evidence to provide a rational basis for setting new lighting power densities in the energy standard. It includes: (a) combining results of new post-occupancy evaluation studies of occupant response before and after moves (or retrofits) to buildings adopting energy-efficient lighting, (b) commissioning lighting simulations to assess strategies for lighting quality as different designs are employed to meet stringent hypothetical lighting power density requirements for different "generic spaces", and (c) working with state energy offices and professional societies to find examples of lighting designs that respond to desired or mandated low lighting power densities.

Results will be available for the 1994 calendar year revision of the energy standard. Continuing research on lighting quality, efficiency, and occupant response should help place the standardization of allocated lighting power densities on a firm scientific basis.

Thursday, February 18

Session Four: 8:30-10:15

HVAC: A Link Between Human Demands and Building Physics

F. Steimle, University of Essen, Essen, Germany

The comfort demands of the inhabitants of buildings are influenced by thermal conditions such as air temperature, air velocity, humidity, and wall temperature but also by indoor air quality and noise level. The building itself has special storage capacities and insulation. The ratio of glass and fixed walls is very important to heat losses in winter and energy gain in summer. These influences affect the comfort in the rooms. The main task for a building's HVAC systems is to fill the gap between the demand and the possibilities of the building. The air changes are caused by air contamination in the building not only by humans but also by the interial design of the room. Very important is the energy demand for the dehumidification of the outdoor air in summer and for heating the building during the winter. Both are affected by the building and influenced by comfort conditions. In this paper, the influences at different times of the year will be described.

The Influence of Temperature and System Operation on the Colonization of Cooling Towers by Legionella Bacteria

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The Legionella genus of bacteria continues to play a role in building-related illness as the causative agent of Legionnaires' disease, a serious pneumonic illness brought about by inhalation of airborne particles containing the microorganism. Legionella survives in cooling-tower water and is able to grow to dangerous concentrations if appropriate environmental factors are satisfied. Transmission to a susceptible host may occur if contaminated particles are emitted in the tower drift. Many of the current practices to control Legionella in cooling towers are either empirical or are based on limited laboratory investigations.

This paper describes findings from a field research study established to meet the need for management strategies based on analytical methodologies. The study investigated correlations between Legionella counts and other environmental factors characteristic of cooling towers. Towers with elevated basin-water temperatures were more frequently colonized and more heavily colonized, regardless of seasonal temperature variations. Ambient dry bulb and wet bulb temperatures gave the lowest correlations with Legionella concentrations. Hours of tower operation and basin-water temperatures gave the highest correlations with Legionella colonization. Legionella concentrations were higher in operating towers than in nonoperating towers, even at similar basin-water temperatures.

There are important ramifications resulting from these findings. Legionella populations in the circulating water are an indicator of the extent of colonization of surfaces in the warmest parts of the system. Control strategies should address the heat exchanger and piping as well as the cooling tower.

Tri-State Homes: A Case Study of Liability for Defective Homes Which Created Unhealthy Environments Causing Personal Injuries

S. J. Schooler, M. M. Mansfield, and J. A. Olson, Lawson and Cates, Madison, WI, U.S.A.

This presentation explores the various legal issues of liability, cause, and health damages for manufacturers, engineers, and inspection agencies where the defective design of buildings causes unhealthy environments for the occupants.

During the 1970s, Tri-State Homes manufactured and sold prefabricated homes in the north central United States. The wall construction consisted of a wood frame with studs which were covered by plywood, a building paper, and siding.

Moisture problems developed in these homes, including excess moisture on windows and sills and mold and mildew growth throughout the house. The occupants also began experiencing health problems much more substantial than other non-Tri-State occupants. These health problems in-